

### **REMARKS**

Claims 1 – 8 have previously been withdrawn and are now canceled as being directed to a non-elected embodiment of this invention.

Claims 9 – 16 and 18 – 22 have been rejected on various grounds. Claim 17 has been indicated to be allowable if rewritten in independent form.

This Amendment and Response includes minor amendments to the Specification for clarification. No new matter has been added. Support for the amendments to the Specification is discussed in part A below.

Independent claims 9 and 14 have been canceled and replaced with new independent claims 29 and 30 respectively. Claim 17 has been canceled and replaced with new independent claim 23, which includes all of the limitations of the base claim (claim 14) and any intervening claims. A new set of dependent claims 24 – 28, dependent on new claim 23, have been added. New claims 24 – 28 correspond respectively to original claims 18 – 22. New independent claims 31 and 32, reciting a specific set of carbon fluoride gases, have also been added.

Original claims 10 – 13 (originally dependent on claim 9) have been made dependent on new claim 29. Original claims 15 – 16 and 18 – 22 (originally dependent on claim 14) have been made dependent on new claim 30. Various minor amendments to the original claims have also been made for clarity and consistency, and in response to the Examiner's objections. Once again, as discussed below, these claim amendments do not add any new matter but rather are fully supported by the Specification as filed. Reconsideration and withdrawal of the several

rejections is respectfully requested based on the amendments and on the remarks and arguments presented below.

A. Support for the Various Amendments

In paragraph 3 of the Office Action of March 29, 2004, the Examiner objected to claim 19 on the ground that the recitation “contact hole is in a range of about 8 – 17” is indefinite “for failing to specify units....” The Examiner, however, failed to quote the immediately preceding portion of this claim. The complete phrase at issue is “wherein an aspect ratio of said contact hole is in a range of about 8 – 17,” (emphasis added). Because this claim is defining a ratio, it should be apparent that there are no units to be specified since comparable units in the numerator and denominator cancel each other out.

The term “aspect ratio” is generally known to those of ordinary skill in this art and, in any event, is defined at page 1, lines 20-22 of the Specification as “vertical size of the device with respect to the horizontal size thereof.” In connection with the present application, the term “aspect ratio” is used to characterize the relative geometry of the contact holes being formed in the silicon oxide layer of a semiconductor device. The “aspect ratio” is the depth of a given contact hole relative to its width, measured in comparable units of length.

Applicants recognize, however, that reciting the aspect ratio of the contact holes as, for example, “8 – 17” could lead to some ambiguity. For clarity and consistency, therefore, in the Specification and Claims, this Amendment has changed the recitations of aspect ratios to the readily understood format of “8:1 to 17:1.” These Amendments to the Specification and Claims accordingly merely clarify the original Specification and do not add any new matter.

In another amendment to the claims, for consistency and clarity all recitations of “auxiliary gas” (e.g., in claims 11 and 12) have been changed to “fluorohydrocarbon gas.” Support for this amendment is found at page 6, line 18 – page 7, line 3 of the original Specification where the etching gas composition of this invention is defined as “consisting essentially of a carbon fluoride gas...together with an auxiliary fluorohydrocarbon gas...” (emphasis added). It is clear that the “auxiliary gas” and the “fluorohydrocarbon gas” of this invention are one and the same.

In another amendment to the claims, new independent claims 29 – 32 recite that the etching gas composition of this invention “consists essentially of” the recited constituent components. This terminology replaces the more open-ended “comprising” terminology of original (now canceled) claims 9 and 14. Support for the “consists essentially of” terminology is found at page 6, line 19 of the original Specification.

In another amendment to the claims, new independent claims 29 and 30 recite that the carbon fluoride gas component of the etching gas composition of this invention has “the general chemical formula  $C_xF_y$ , in which  $y/x$  is a ratio having a value less than 2 and which chemical formula includes at least a double or a triple carbon-carbon bond...” Support for this claim language identifying the carbon fluoride gas component is found at page 6, lines 19-21; page 7, lines 5-7; page 7, lines 19-21; and page 10, line 21 – page 11, line 6; and also in Fig. 2B.

In another amendment to the claims, new independent claims 29 and 30 recite that the fluorohydrocarbon gas component of the etching gas composition of this invention has “the general chemical formula  $C_kH_lF_m$ , in which  $k$ ,  $l$  and  $m$  are positive integers...” Support for this

claim language identifying the fluorohydrocarbon gas component is found at page 6, line 21 – page 7, line 3, and again at page 7, lines 5-8 of the Specification.

In another amendment to the claims, new independent claims 29 and 30 recite that the etching method of this invention forms contact holes “of substantially the same depth and with a high aspect ratio, each having top and bottom portions, wherein the top portion of each contact hole is only very slightly wider than the bottom portion....” Support for this added claim language is found at various locations, such as at page 1, lines 9-11; page 8, lines 9-11; page 16, lines 1-4; page 17, lines 3-7; page 18, Table 1 and lines 13-15; page 22, Table 2; and page 23, lines 2-4 of the Specification and also in Figs. 5B and 7A – D of the drawings.

In another claim amendment, new independent claims 31 and 32 recite that the carbon fluoride gas component of the etching gas composition of this invention is “selected from the group consisting of  $C_4F_6$ ,  $C_3F_4$ ,  $C_2F_2$ , and mixtures thereof....” Support is found at page 7, line 21 of the Specification and in original claims 3, 10 and 15.

In another claim amendment, claim 12 was amended to recite that “the ratio of the volumetric flow rate...is in a range of about 0.1 to 1.0.” Support is found at page 14, lines 7-9 of the Specification.

Accordingly, no new matter has been added by the present amendments.

#### B. Sec. 112 Rejections

In para. 3 of the Office Action of March 29, 2004, the Examiner rejected claim 9 under 35 USC §112 on the ground that “the ratio of fluorine...” lacks antecedent basis. Claim 9 has

been canceled. Corresponding new claim 29 has revised the claim language to obviate this ground of rejection.

In para. 3 of the Office Action of March 29, 2004, the Examiner rejected claim 19 under 35 USC §112 on the ground that “contact hole is in a range of about 8 – 17” is indefinite. Claim 19 has now been amended and, in view of the comments in part (A) above of the Remarks, Applicants respectfully submit that this ground of rejection has been obviated.

C. Sec. 102 Rejection – Claims 9 - 13

In para. 5 of the Office Action of March 29, 2004, the Examiner rejected claims 9 – 13 under 35 USC §102(e) as being anticipated by the Okamoto ‘435 reference. Claim 9 has herein been canceled and replaced by new claim 29. Dependent claims 10 – 13 are now dependent on new claim 29.

The Okamoto ‘435 reference is certainly directed to the same general field as the present invention, namely to a method for etching a silicon oxide layer of a semiconductor device using an etching composition containing a carbon fluoride gas. But, Okamoto ‘435 has a very specific desired objective which, in turn, dictates the use of very specific etching gas compositions and process parameters that differ in important ways from the present invention as now claimed.

Specifically, as discussed at col. 1, lines 47-43, Okamoto ‘435 states that an object of that invention is to use a plasma etching method to simultaneously form holes in an insulating film extending from a surface down to wires located at different depths in the insulating film such that the hole to the shallower wire is not “over-etched.” Okamoto ‘435 further teaches that establishing the right balance between too-much and too-little etching depends on carefully

controlling the many operating condition variables. For example, at col. 1, lines 59-67, Okamoto '435 states:

“As a result the present inventors have found that, where the ratio of a fluorocarbon-containing gas, such as C<sub>4</sub>F<sub>8</sub> gas or C<sub>5</sub>F<sub>8</sub> gas, relative to the whole process gas is extremely low as compared to conventional values, it is possible to reliably etch the insulating film down to a wiring layer at a deeper position and to prevent that part of the insulating film adjacent to a wiring layer at a shallower position from being over-etched,” (emphasis added).

Also at col. 2, lines 36-43, Okamoto '435 states:

“Where the fluorocarbon-containing gas consists of C<sub>4</sub>F<sub>8</sub> gas or C<sub>5</sub>F<sub>8</sub> gas, the flow ratio of the CO gas relative to the C<sub>4</sub>F<sub>8</sub> gas or C<sub>5</sub>F<sub>8</sub> gas is preferably set to be from 35 to 200. With this condition, it is ensured to etch the oxide film down to the wiring layer at the deeper position, while preventing the insulating film from being over-etched around the wiring layer at the shallower position.”

By contrast, the principal object of the present invention is to etch contact holes having substantially the same depth (rather than of two different depths) and also having the properties of “having a high aspect ratio and a good vertical profile” (page 1, lines 9-10 of the Specification) such that “the top portion of [each] contact hole...is only very slightly wider than the bottom portion, thereby resulting in a contact hole having a good (desirable) vertical profile” (page 17, lines 1-5 of the Specification).

In order to realize this objective, the Applicants have determined that the etching process must be carried out using a particular etching composition which must include a carbon fluoride gas “of the general chemical formula C<sub>x</sub>F<sub>y</sub>, in which y/x is a ratio having a value less than 2 and which chemical formula includes at least a double or a triple carbon-carbon bond....” At page 10, line 20 – page 12, line 11, in connection with a detailed discussion of Figs. 2A, 2B and 3, the

present application discusses a likely technical explanation for the surprising and unexpected phenomenon that the use of an etching gas composition that includes a carbon fluoride gas having at least a double or a triple carbon-carbon bond, in combination with specified proportions of other components, is able to create contact holes having both a high aspect ratio and also a significantly better vertical profile than contact holes formed using conventional techniques, and also without excessive removal of the silicon oxide insulating layer. These differences are clearly illustrated by comparing Fig. 1B of the present application (illustrating the typical result of a prior art etching procedure) with Fig. 4B illustrating the result of an etching carried out in accordance with an embodiment of this invention. Neither Okamoto '435 nor any of the other cited prior art teaches or in any way suggests the criticality of selecting a carbon fluoride gas having at least a double or a triple carbon-carbon bond.

Applicants acknowledge that Okamoto '435 teaches that  $C_5F_8$  gas, a gas that has a double carbon-carbon bond, could be substituted for the preferred  $C_4F_8$  gas in the Okamoto '435 etching composition, but there is no suggestion of any reason for doing so, and certainly no recognition that this selection would dramatically improve the vertical profile of the resulting contact holes. As taught at page 11, lines 3-5, of the present application,  $C_5F_8$  gas is considerably more expensive than the more conventional  $C_4F_8$  gas in such etching applications. Accordingly, no one would choose  $C_5F_8$  gas for use in an etching composition without some known, recognized advantage or benefit in doing so. Only the present application teaches what that advantage is.

Although Okamoto '435 has illustrated the contact holes formed by the Okamoto '435 method (for example, in Figs. 5, 6 and 7) as having substantially vertical sides, one of ordinary skill in this art would clearly recognize that the drawings in Okamoto '435 are merely schematic

illustrations (or, perhaps, wishful thinking!) and not a truly accurate representation of the shape of the actual contact holes. This can readily be seen by comparing the illustrations of contact hole geometry in Okamoto '435 with the much more realistic illustrations found in the other cited prior art references, for example in Figs. 4 and 5 of Chen '822 and in Figs. 2 – 6 of Jeng '488, which clearly show sloping sidewalls. In addition, Okamoto '435 fails to teach or suggest the oxygen component of a preferred embodiment of the etching composition of this invention, as now recited in new claim 29.

For all of these reasons, Applicants respectfully request that the Examiner reconsider and withdraw this ground of rejection.

D. Sec. 102 Rejection – Claims 14 – 16

In para. 6 of the Office Action of March 29, 2004, the Examiner rejected claims 14 – 16 under 35 USC §102(e) as being anticipated by the Okamoto '435 reference. Claim 14 has herein been canceled and replaced by new claim 30. Dependent claims 15 and 16 are now dependent on new claim 30.

The basis for this rejection was substantially the same as that previously applied to claims 9 – 13. New claim 30 (replacing rejected claim 14) has been drafted to parallel new claim 29, which was discussed in part (C) above, including various recitations concerning the etching composition and the geometry of the resulting contact holes. For the same reasons discussed above relative to claim 29, Applicants respectfully request that the Examiner reconsider the relevance of Okamoto '435 to new claim 30 in view of the remarks presented in part (C) above, and, on the basis of the amendments and arguments, withdraw this ground of rejection.



E. Sec. 103 Rejection – Claim 18

In para. 9 of the Office Action of March 29, 2004, the Examiner rejected claim 18 under 35 USC §103 as being unpatentable over Okamoto '435, as applied to claim 14, and further in view of Chen '822. As previously noted, claim 14 has been canceled and replaced by new claim 30. Claim 18 is now dependent on new claim 30.

The deficiencies of the Okamoto '435 reference relative to the present application, and specifically to new claims 29 and 30, have been thoroughly discussed above. Chen '822 does not make up for these fundamental deficiencies. Chen '822 appears to have been cited by the Examiner solely to meet the claim limitation of claim 18 that the “photoresist is a photoresist applicable for DUV wavelength.”

Chen '822 is directed to a method for etching sub-quarter micron openings in an insulative layer of a semiconductor device. The Chen '822 method uses a hardmask formed of carbon-enriched titanium nitride which has a high selectivity for etching contact. According to Chen '822, the high selectivity of the carbon-enriched titanium nitride hardmask makes this process “highly desirable for DUV photolithography.”

However, neither Okamoto '435 nor the present invention uses a carbon-enriched titanium nitride hardmask as taught by Chen '822. There is no teaching or suggestion of why one skilled in this art would be led to combine the teachings of Chen '822 with those of Okamoto '435. Specifically, in what way would the carbon-enriched titanium nitride hardmask of Chen '822 contribute to the realization of the objective of Okamoto '435 to simultaneously etch contact holes of two different depths? Furthermore, even if this combination of references were made, the result would still not be anything remotely approaching the present invention.

Similar to Okamoto '435, Chen '822 fails to recognize the criticality of using an etching composition that includes a carbon fluoride gas having at least a double or a triple carbon-carbon bond in order to produce contact holes having a high aspect ratio and a superior vertical profile. The etching compositions taught by Chen '822 use only the conventional carbon fluoride gases such as  $\text{CF}_4$ ,  $\text{C}_2\text{F}_6$ , and  $\text{C}_4\text{F}_8$  (see col. 4, lines 65-67), perhaps in combination with a fluorohydrocarbon such as  $\text{CHF}_3$ . But,  $\text{CF}_4$ ,  $\text{C}_2\text{F}_6$  and  $\text{C}_4\text{F}_8$  do not satisfy the claim requirements that the ratio of  $y/x$  be less than 2 and include at least a double or a triple carbon-carbon bond.

For all of these reasons, Applicants respectfully request that the Examiner reconsider and withdraw this ground of rejection.

F. Sec. 103 Rejection – Claims 19 – 21

In para. 10 of the Office Action of March 29, 2004, the Examiner rejected claims 19 – 21 under 35 USC §103 as being unpatentable over Okamoto '435. The Examiner acknowledges that Okamoto '435 “is silent about the specific ranges of the aspect ratio of the contact hole, the diameter of the contact hole, and the thickness of the silicon oxide layer” as specified in the respective claims. The Examiner contends, however, that it would have been obvious to one having ordinary skill in the art to select any combination of such parameters.

Claims 19 – 21 are now dependent on new claim 30. The Examiner is respectfully referred to part (C) above which discusses in detail the many deficiencies of Okamoto '435 relative to the presently-pending claims. In particular, as previously discussed, Okamoto '435 fails to teach or even recognize the criticality of using an etching composition that includes a

carbon fluoride gas having at least a double or a triple carbon-carbon bond in order to produce contact holes having a high aspect ratio and a superior vertical profile.

Although one skilled in this art might well recognize the desirability of forming contact holes having such properties, Okamoto '435 is directed to a completely different and, in certain respects, incompatible objective of simultaneously etching contact holes to different depths. Furthermore, nothing in Okamoto '435 would teach or suggest to one skilled in the art how to create contact holes having the desirable properties of a high aspect ratio and a superior vertical profile.

For all of these reasons, Applicants respectfully request that the Examiner reconsider and withdraw this ground of rejection.

G. Sec. 103 Rejection – Claim 22

In para. 11 of the Office Action of March 29, 2004, the Examiner rejected claim 22 under 35 USC §103 as being unpatentable over Okamoto '435, as applied to claim 14, and further in view of Jeng '488. As previously noted, claim 14 has been canceled and replaced by new claim 30. Claim 22 is now dependent on new claim 30.

The deficiencies of the Okamoto '435 reference relative to the present application have been thoroughly discussed above. Jeng '488 does not make up for these fundamental deficiencies. Jeng '488 appears to have been cited by the Examiner solely to meet the claim limitations of claim 22 that "said semiconductor device is a DRAM device, and said contact hole is an MC (metal contact hole) for connecting a metal layer formed on said silicon oxide layer formed on a capacitor with an impurity doped region."

Jeng '488 is directed to a method for making a semiconductor structure having borderless and self-aligned polysilicon and metal contact landing plugs for multilevel interconnections on an integrated circuit board by using successive etch-stop layers to selectively control etching. However, there is no teaching or suggestion here of why one skilled in this art would be led to combine the teachings of Jeng '488 with those of Okamoto '435 in view of the fact that these references are directed to different semiconductor structures, having different utilities, and to different fabrication problems and objectives.

Furthermore, even if this combination of references were made, the result would still not be anything approaching the present invention. Similar to Okamoto '435, Jeng '488 teaches the use of both  $C_4F_8$  and  $C_5F_8$  as etchant gases, but fails to recognize the criticality of using an etching composition that includes a carbon fluoride gas having at least a double or a triple carbon-carbon bond in order to produce contact holes having a high aspect ratio and a superior vertical profile in accordance with the present invention.

For all of these reasons, Applicants respectfully request that the Examiner reconsider and withdraw this ground of rejection.

#### H. Allowable Subject Matter

In para. 12 of the Office Action of March 29, 2004, the Examiner noted that claim 17 "would be allowable if rewritten in independent form including all of the limitations of the base claim and any intervening claims." Applicants thank the Examiner for the courtesy of indicating such allowable subject matter.

Claims 17 has herein been canceled and rewritten as new independent claim 23. New claim 23 contains all of the limitations of base claim 14 as well as the claim recitations of claim 17. Accordingly, new claim 23 is clearly allowable.

This Amendment has also added new claims 24 – 28, which are substantially identical respectively, to original claims 18 –22, but are dependent on new claim 23. Accordingly, new claims 24 – 28 should also be deemed clearly allowable.

This Amendment has also added new claims 31 and 32. New claim 31 is generally based on original (now canceled) claim 9, but recites a narrower set of carbon fluoride gas components for the etching composition, namely, “a carbon fluoride gas selected from the group consisting of  $C_4F_6$ ,  $C_3F_4$ ,  $C_2F_2$ , and mixtures thereof.” Similarly, new claim 32 is generally based on original (now canceled) claim 14, but recites the narrower set of carbon fluoride gas components. None of the cited references teach or suggest using any of carbon fluoride gases recited in new claims 31 and 32 as components of an etching gas composition for semiconductor applications. Accordingly, Applicants respectfully submit that new claims 31 and 32 are also clearly allowable.

#### **Summary and Conclusions**

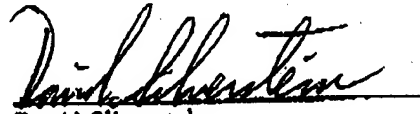
Based on the foregoing arguments, it is respectfully submitted that Claims 10 – 16 and 18 – 32 pending in this application are now in condition for allowance, and such allowance is

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respectfully requested. If prosecution of the application can be expedited by a telephone conference, the Examiner is invited to call the undersigned at the number given below.

Respectfully submitted,

Date: June 28, 2004  
Mills & Onello, LLP  
Eleven Beacon Street, Suite 605  
Boston, MA 02108  
Telephone: (617) 994-4900  
Facsimile: (617) 742-7774  
J:\sam\0256\amendments.doc

  
David Silverstein  
Registration Number 26,336  
Attorney for Applicant